A COMMERCIAL IMPLEMENTATION OF SPACE LINK EXTENSION

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ABSTRACT

Standardization and Commercialization reduce development and maintenance costs. The Consultative Committee for Space Data Systems (CCSDS) created recommendations for space link standards. The implementation of the CCSDS recommendations enabled commercial-off-the-shelf (COTS) product development and resource sharing between space systems and groundstations; however, the ground link remained ad hoc and mission specific. Groundstation system engineers faced the problem of supporting disparate protocols. To address this problem, CCSDS created a recommendation that extends the space link standards to the ground link; named Space Link Extension (SLE).

With the implementation and adoption of the SLE standard comes a line of commercial products from Avtec Systems. These products include full data handling systems, test clients, and software libraries. System engineers may design these products into new systems or use them to transition existing systems to SLE.

1. INTRODUCTION

The Programmable Telemetry Processor (PTP) from Avtec Systems is a COTS front-end data system for groundstations. Its modular software design enables a powerful and highly user-configurable system. The main hardware component is the Avtec Monarch PCI card. The Monarch has full-duplex RS-422 and TLL interfaces and is capable of frame synchronization, optional Reed-Solomon error correction, CRC error detection, and randomization; all adhering to the CCSDS Space Link Recommendations for command and telemetry. Other boards are available for Viterbi decoding, bit synchronization, and accurate time stamping.

PTP software modules are routed together to perform CCSDS virtual channel and packet processing, data simulation, data archiving, and format conversion. Spacecraft command and telemetry data may also be transferred to and from the PTP over IP-based network protocols.

The CCSDS space link recommendations [2][3] have enabled the implementation of a generic COTS product; however, a lack of a ground link standard has forced the implementation of several ground link data formats. Each new format not only adds cost and complexity to the PTP, but they add complexity to groundstation cross support management.

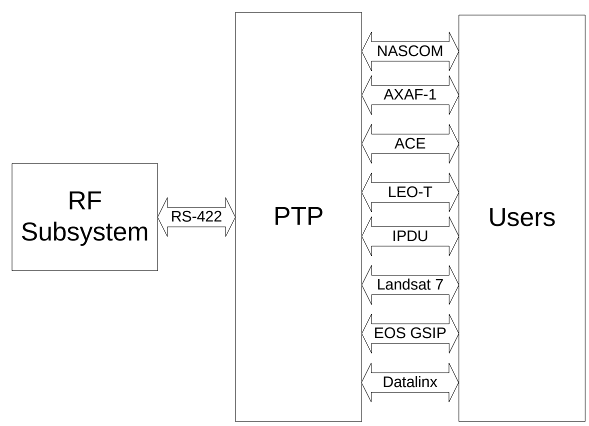

Figure 1. Example of multiple interface support required without SLE

To address this problem, CCSDS defined SLE [1]. The first implementation of SLE was for the International Gamma-Ray Astrophysics Laboratory (INTEGRAL) mission. To support INTEGRAL, the European Space Agency (ESA) requested the use of the Goldstone 26M groundstation managed by the Jet Propulsion Laboratory (JPL) for the National Aeronautics and Space Administration (NASA). They selected SLE as the inter-agency data transfer protocol. ESA proceeded to define an application program interface (API) [8][10][11][12] and a TCP/IP transfer definition [9]. JPL and ESA independently implemented the standard. Part of the JPL implementation was funded to Avtec Systems as an SLE upgrade to existing PTPs.

2. SLE TRANSFER SERVICES

SLE consists of seven return services and four forward services. The primary services defined and implemented for

INTEGRAL are Forward CLTU, Return All Frames, and Return Channel Frames.

Forward CLTU (FCLTU) [5] allows the user to send commands to the groundstation to be buffered and forwarded to the spacecraft. The CLTUs are transferred without modification according to the CCSDS Physical Link Operation Procedure (PLOP) [4]. The PLOP defines acquisition and idle sequences. The Avtec PLOP implementation permits commands to be sent back-to-back to create a bitstream uplink; therefore, FCLTU may be used for non-CCSDS systems.

Return All Frames (RAF) [6] allows the user to receive all telemetry frames from a single physical channel with three modes of delivery: Online Timely, Online Complete, and Offline. The service is intended for CCSDS Telemetry frames, but the Avtec implementation has options for other framed telemetry, such as TDM, and unframed, bitstream telemetry. CCSDS will recommend support for these types of telemetry in the future.

Return Channel Frames (RCF) [7] is similar to RAF, but it allows the user to receive frames on a specific virtual channel. Since virtual channels are a CCSDS concept, this service may only be used by CCSDS systems.

Avtec has implemented PTP modules for these three SLE transfer services. Modules are currently available for both the provider and user sides of each service.

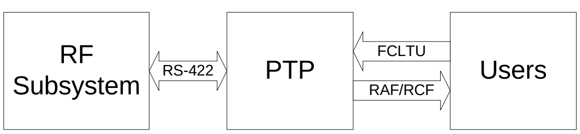

Figure 2. SLE simplifies the ground-link interfaces.

3. CURRENT USERS

Deep Space Network Operations

SLE-enabled PTPs are currently in the field and in the lab. A PTP is installed on all three nodes of the JPL 26M Deep Space Network (DSN): Goldstone, California; Canberra, Australia; and Madrid, Spain. These PTPs are equipped with FCLTU provider modules.

The Goldstone node currently supports primary SLE commanding for the INTEGRAL mission. Additionally, the Genesis project uses SLE commanding on all three nodes of the 26M DSN, and JPL is encouraging the use of SLE for all new DSN users.

CSOC Feasibility Study

The Consolidated Space Operations Contract (CSOC) is currently using two PTPs to investigate the feasibility of SLE to support all NASA missions [13][14]. These PTPs are equipped with provider and user versions of the forward and return modules. Avtec has worked closely with CSOC to customize its implementation for special situations. Some of these modifications are being adopted into future SLE recommendations.

The PTPs were installed at the NASA WFF Microwave Telemetry Test Laboratory and the NOAA WFF CDA Station, both at Wallops Island, VA. CSOC successfully conducted SLE tests between these sites and the LM SLE Lab in Houston, TX. CSOC also conducted live SLE tests with the NASA WIRE and NASA COBE satellites. All tests exercised the FCLTU, RAF, and RCF services.

Air Force Satellite Control Network Compatibility Test

Avtec loaned a PTP to the Air Force to study the feasibility of using SLE to convert a circuit-switched network architecture to an IP-packet-switched circuit architecture [15]. This PTP was equipped with provider versions of the forward and return modules. The forward bitstream data was sent to the PTP using the FCLTU service. The loopback data was returned to the user using an RAF instance. Range data was also returned using an RAF instance. This is a good example of using SLE for non-CCSDS use.

4. SYSTEM SOLUTIONS

Groundstation Front-End Processor

The PTP equipped with the SLE provider modules and Monarch hardware is easily configured as a groundstation SLE front-end processor.

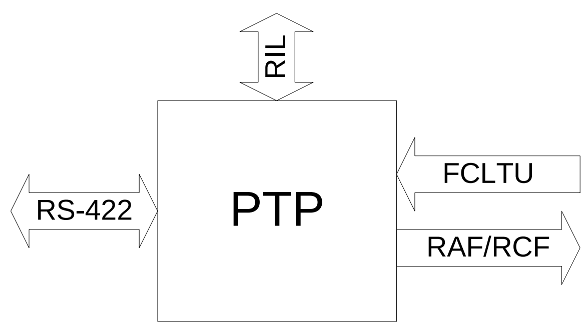

Figure 3. PTP may be configured as an SLE front-end processor at the groundstation.

In this basic configuration, the PTP receives command packets via the FCLTU transfer service. The packets are buffered and released to the RS-422 interface according to the SLE recommendation. Packetized telemetry frames received from the RS-422 interface are returned to one or more users using RAF or RCF service. PTP management is performed through a custom remote interface library (RIL). The RIL is built on TCP/IP. Versions of the RIL are available for Windows, Sun, and Linux; and a Windows client is included to perform manual PTP configuration.

Some groundstations may wish to transition from existing interfaces to SLE. PTP still supports the most common TCP/IP-based interfaces. These interfaces may then be used in a hybrid SLE configuration.

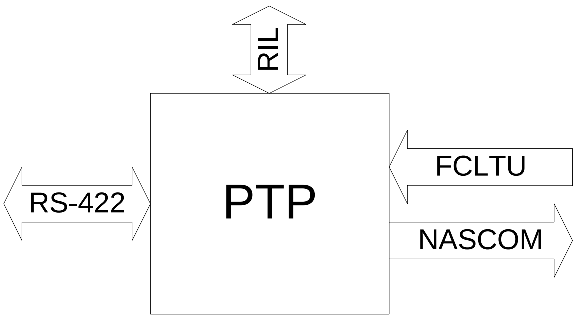

Figure 4. PTP supports many of the common user interfaces. This is an example if an SLE hybrid configuration using SLE to receive commands and NASCOM blocks to return telemetry.

SLE Protocol Gateway

It is clear that groundstations may use SLE to reduce costs. Future mission control centers and data processing centers using SLE will be able to save by sharing resources with other SLE missions. However, current missions cannot take advantage of resource sharing without converting existing transfer protocols to SLE. The flexibility of the PTP may be harnessed to act as an SLE protocol gateway.

This PTP would be equipped with the SLE user modules and the appropriate format modules for the custom interface. This PTP may or may not require any hardware, depending on the requirements.

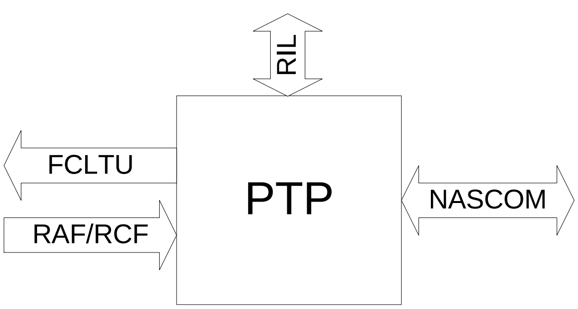

Figure 5. PTP may be configured as an SLE protocol gateway. In this example, the PTP converts between NASCOM and SLE.

SLE Frames Router

SLE was designed to work in stages modeling the CCSDS space link standard. SLE defines these stages as functional groups (FGs). Each FG provides or uses SLE transfer services; therefore, an FG defines a node in a distributed system, where information is sent between the FGs via SLE transfer services.

Return Frame Processing is one of these FGs. This FG uses an RAF service and provides RCF services. Since it is a node on a distributed system, the Return Frame Processing FG may be used to minimize the data throughput from the groundstation by requiring a single RAF service from the remote groundstation and distributing the frames to multiple users over a local network.

A PTP may be configured to implement the Return Frames Processing FG. This PTP would not contain hardware interfaces, but would be equipped with a combination of provider and user SLE modules. The frames router interfaces are not limited to the traditional RAF to RCF configuration. It may also be configured to convert RAF to a combination of RAF and RCF instances, and it may be configured to convert RCF to multiple RCF instances.

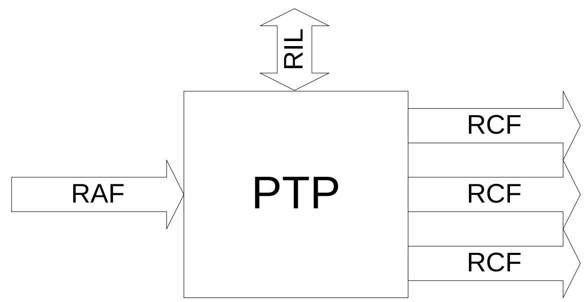

Figure 6. PTP may be configured used as an SLE frames router. The traditional configuration is shown.

5. SUPPORT SOFTWARE

SLE is an asymmetric interface. Each SLE service has a provider side and a user side. New SLE systems require emulation of their peers for development and testing purposes. Avtec is developing software to emulate SLE users and providers. They will have full scripting capability for creating test scripts.

SLE FCLTU Test Client

The FCLTU Test Client implements the client (or user) side of the FCLTU service. It may be used as a test tool for the development and testing of FCLTU Provider implementations or installations.

JPL is using the SLE FCLTU Test Client to test all of their FCLTU Provider implementations. Software will soon be available for an SLE RAF/RCF Test Client, an SLE FCLTU Test Server, and an SLE RAF/RCF Test Server.

6. SOFTWARE LIBRARIES

The SLE API is available as free C++ Unix source code through JPL. Custom SLE implementations may use this source code or purchase 3rd-party software licenses. Avtec used the JPL source code as a reference when developing Avtec's implementation of the SLE API for Windows.

SLE API Library

This library was initially intended for internal use of our system products. We have since decided to make user-side licenses available as a COTS product. Avtec partners may purchase provider-side licenses on a case-by-case basis.

The Avtec SLE API is implemented as a set of Microsoft COM components. As much as possible, the API was developed to the SLE API specification to allow for cross implementation capability. A few extended functions are added where the specification violated the Microsoft COM standard. These extended functions must be used if the user software is compiled in a different environment from the SLE components.

SLE API Helper Components

The SLE API was designed as an abstraction layer to SLE; however, many SLE-specific functions must still be implemented by the application. Avtec created helper components as an additional SLE abstraction layer. These components greatly simplify the API, and reduce the end-user implementation details. The user-side SLE helper components are available as COTS products, including an SLE CLTU User component for FCLTU user implementations, and an SLE Frames User component for RAF/RCF user implementations.

7. CONCLUDING REMARKS

SLE has shown the capability and probability of becoming the standard ground-link protocol of space data systems, creating the reality of cross compatibility between groundstations, control centers, and data centers.

Avtec Systems offers additional cost reduction through the commercialization of SLE products. Avtec offers products for new and transitional systems. SLE-enabled PTPs have helped to pioneer SLE as an international standard, and are being used as a benchmark for SLE feasibility testing.

8. REFERENCES

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